- Atmospheric Infrared Sounder (AIRS)
- Advanced Microwave Sounding Unit (AMSU)
- Humidity Sounder from Brazil (HSB)

- Aqua Spacecraft

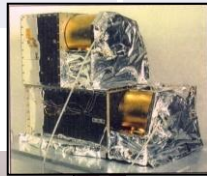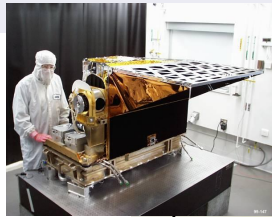*Improving Weather and Climate Prediction*

A-Train Symposium
Forecast Improvement and Applications of the AIRS on Aqua
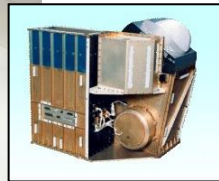
October 26, 2010
New Orleans, LA

T. Pagano
California Institute of Technology, JPL

NASA AQUA Spacecraft launched from Vandenberg on May 4, 2002
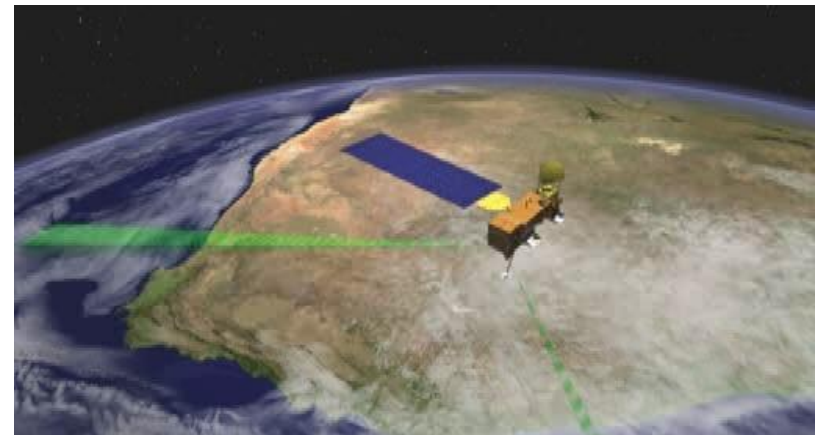

AMSU

AIRS

HSB

NGST

Delta 2

- AIRS/AMSU/HSB Known as AIRS Sounding Suite
- Orbit
  - 705 km, polar sun synchronous ascending, 1:30 PM
- Status
  - AIRS/AMSU-A/HSB powered on May 2002
  - AIRS Fully Operational
    Expected to be operational beyond 2018
  - AMSU: Fully Operational Except Ch 4, 5
  - HSB failed to restart – February 2003

A-Train Symposium: Pagano, October 26, 2010
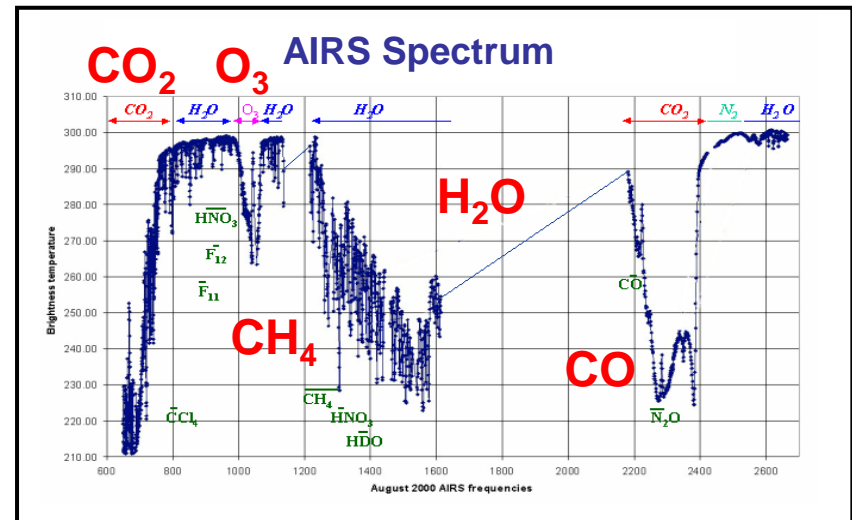
The Atmospheric Infrared Sounder on NASA's EOS Aqua Spacecraft

AIRS Characteristics

- Launched: May 4, 2002, Aqua S/C
- Orbit: 705 km, 1:30pm, Sun Synch
- IFOV : 1.1° x 0.6° (13.5 km x 7.4 km)
- Scan Range: ±49.5°
- Solid State Grating Spectrometer
  - IR Spectral Range: 3.74-4.61 µm, 6.2-8.22 µm, 8.8-15.4 µm, $(\lambda/\Delta\lambda) \approx 1200$
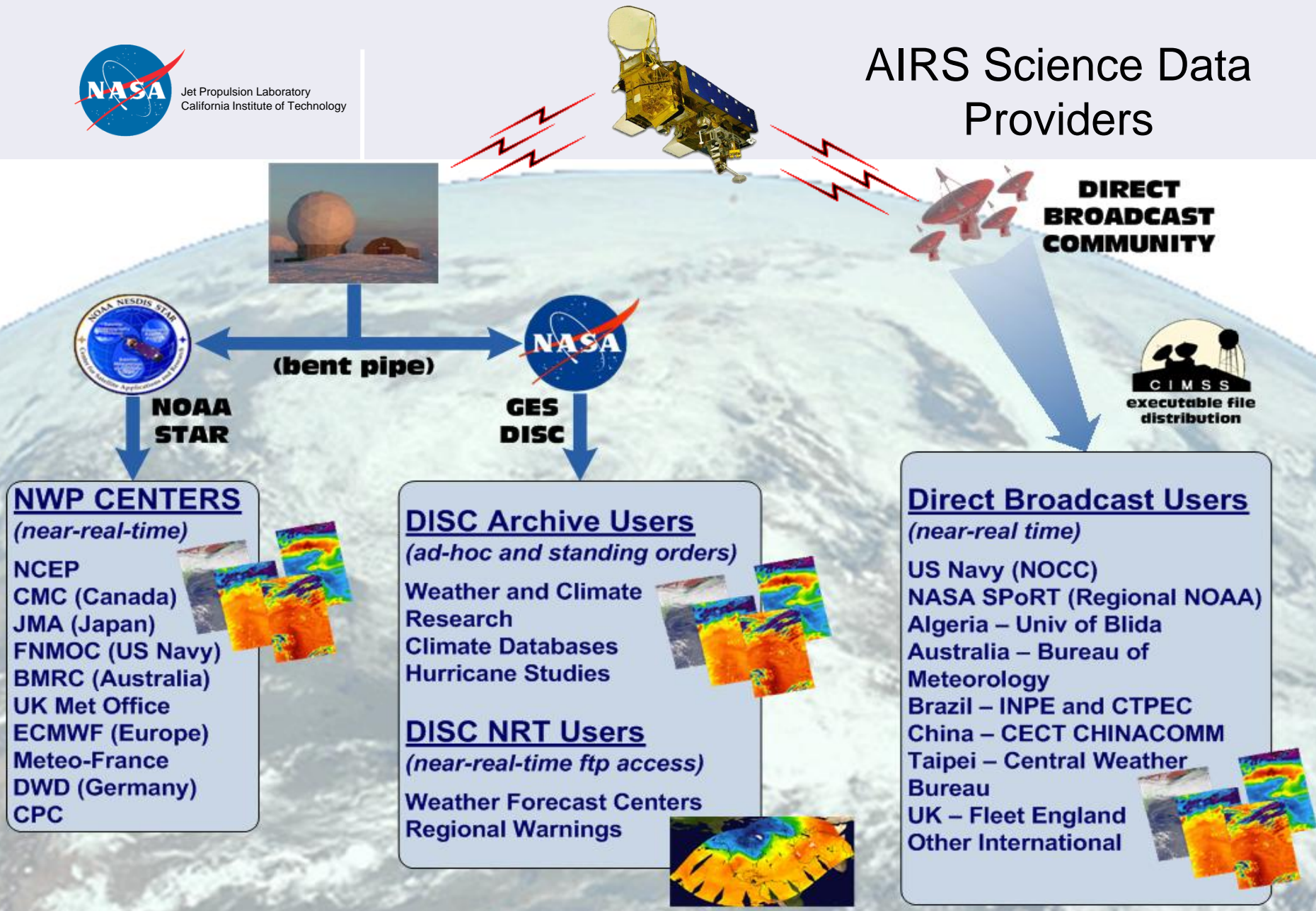
Science Objectives

- Improve Weather Forecasting
  - AIRS Data Assimilated into Operational Forecasts at NWP Centers Worldwide
- Improve Climate Prediction
  - AIRS Provides Unprecidented 3D view of water vapor, temperature and clouds
- Observe Greenhouse Gases
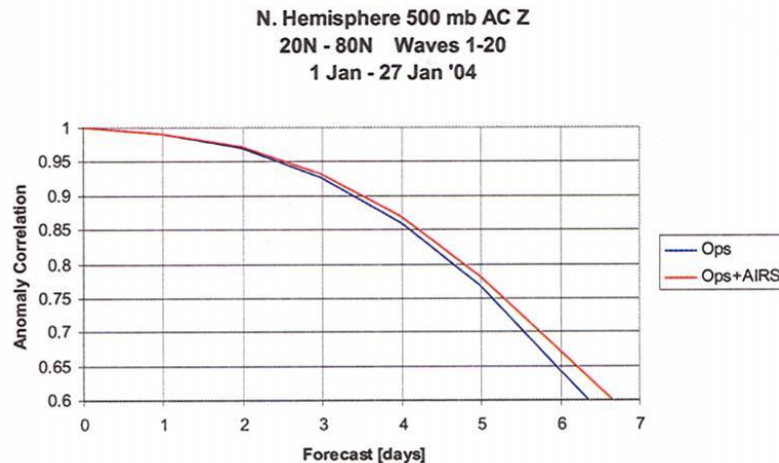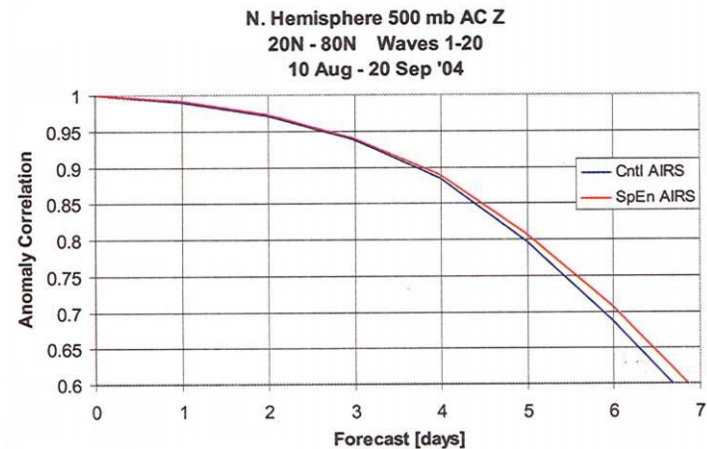 - First Global Maps of Mid-Trop CO2

AIRS

AIRS Spectrum

AIRS Science Data Providers

DIRECT BROADCAST COMMUNITY

(bent pipe)

NOAA STAR

GES DISC

CIMSS executable file distribution

NWP CENTERS
(near-real-time)

NCEP
CMC (Canada)
JMA (Japan)
FNMOC (US Navy)
BMRC (Australia)
UK Met Office
ECMWF (Europe)
Meteo-France
DWD (Germany)
CPC

DISC Archive Users
(ad-hoc and standing orders)

Weather and Climate
Research
Climate Databases
Hurricane Studies

DISC NRT Users
(near-real-time ftp access)

Weather Forecast Centers
Regional Warnings

Direct Broadcast Users
(near-real time)

US Navy (NOCC)
NASA SPoRT (Regional NOAA)
Algeria – Univ of Blida
Australia – Bureau of
Meteorology
Brazil – INPE and CTPEC
China – CECT CHINACOMM
Taipei – Central Weather
Bureau
UK – Fleet England
Other International

http://airs.jpl.nasa.gov   **http://disc.sci.gsfc.nasa.gov/**

A-Train Symposium: Pagano, October 26, 2010

AIRS Data Continues
to Improve Forecasts

Initial inclusion of AIRS data

N. Hemisphere 500 mb AC Z
20N - 80N   Waves 1-20
1 Jan - 27 Jan '04

5 Hours in 6 Days (1 in 18 Footprints)
October 2004

Utilizing All AIRS Footprints

N. Hemisphere 500 mb AC Z
20N - 80N   Waves 1-20
10 Aug - 20 Sep '04

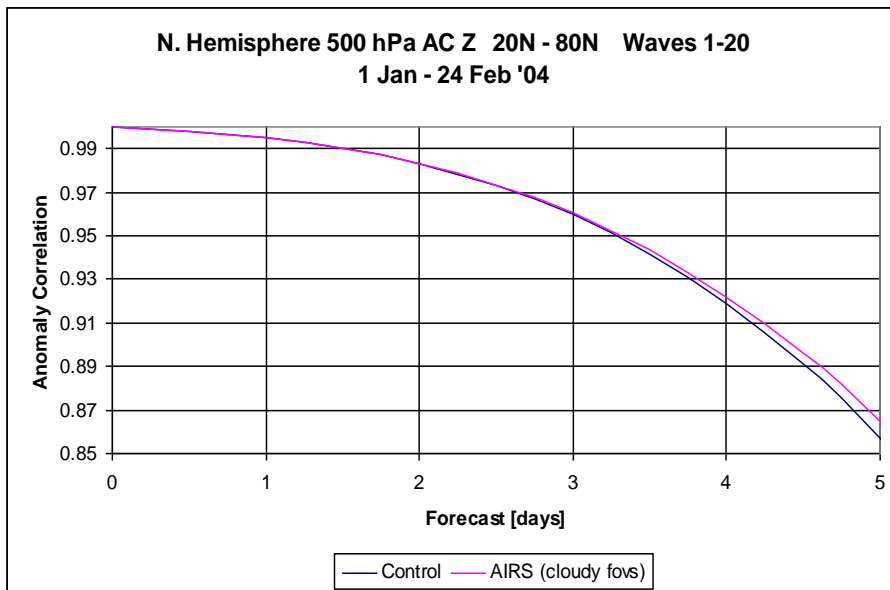**Additional 5 Hours in 6 Days**

"This AIRS instrument has provided the most significant increase in forecast improvement in this time range of any other single instrument."

Retired Navy Vice Admiral Conrad C. Lautenbacher, Jr., Ph.D., Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator, August 24, 2005
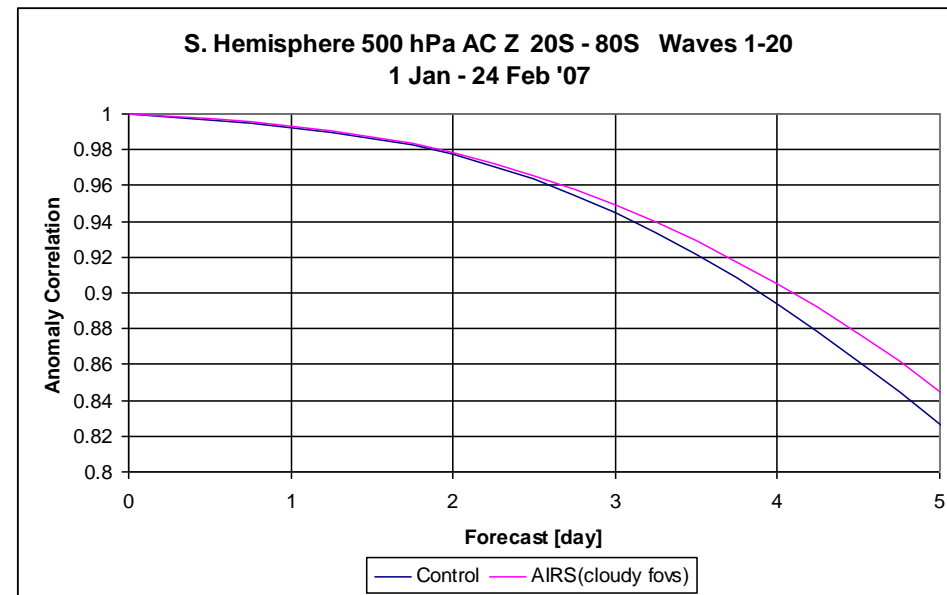
Le Marshall, J., J. Jung, J. Derber, M. Chahine, R. Treadon, S. J. Lord, M. Goldberg, W. Wolfc, H. C. Liu, J. Joiner, J. Woollen, R. Todling, P. van Delst, and Y. Tahara (2006), "Improving Global Analysis and Forecasting with AIRS", Bulletin of the American Meteorological Society, 87, 891-894, doi: 10.1175/BAMS-87-7-891

5

A-Train Symposium: Pagano, October 26, 2010

1 January – 24 February 2007

Operational GFS system

N. Hemisphere 500 hPa AC Z 20N - 80N   Waves 1-20
1 Jan - 24 Feb '04

Anomaly Correlation vs Forecast [days]

Control — AIRS (cloudy fovs)

S. Hemisphere 500 hPa AC Z 20S - 80S   Waves 1-20
1 Jan - 24 Feb '07
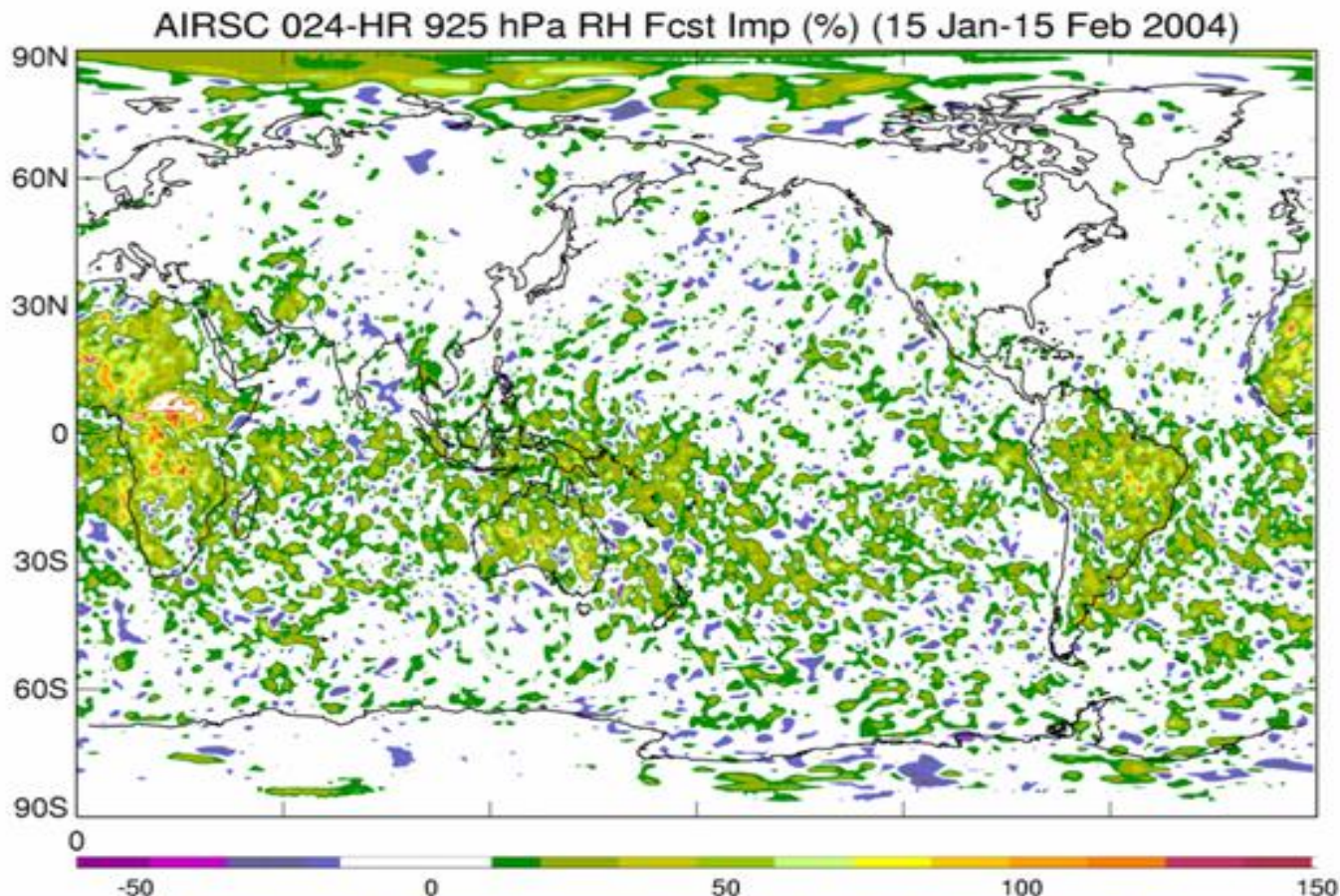
Anomaly Correlation vs Forecast [day]

Control — AIRS(cloudy fovs)

Le Marshall, J., Jung,J., , Goldberg, M.., Barnet, C., Wolf, W., Derber, J., Treadon, R. and S. Lord. 2008. Using Cloudy AIRS Fields of View in Numerical Weather Prediction . *Aust. Meteor. Mag.* **, 57, 249-254.**

AIRSC 024-HR 925 hPa RH Fcst Imp (%) (15 Jan-15 Feb 2004)

Forecast Impact improvement/degradation (%) of the 12 hr Relative Humidity forecast at 925 hPa.

Le Marshall, J., J. Jung, J. Derber, M. Chahine, R. Treadon, S. J. Lord, M. Goldberg, W. Wolf, H. C. Liu, J. Joiner, J. Woollen, R. Todling, P. van Delst, and Y. Tahara (2006), "Improving Global Analysis and Forecasting with AIRS", Bulletin of the American Meteorological Society, 87, 891-894, doi: 10.1175/BAMS-87-7-891

A-Train Symposium: Pagano, October 26, 2010

Jet Propulsion Laboratory
California Institute of Technology

• Microwave satellite measurements (AMSU-A) are responsible for 18% of the forecast error reduction
• Infrared measurements (AIRS and IASI) for 12% each
• 10% of error reduction is due to radio occultation
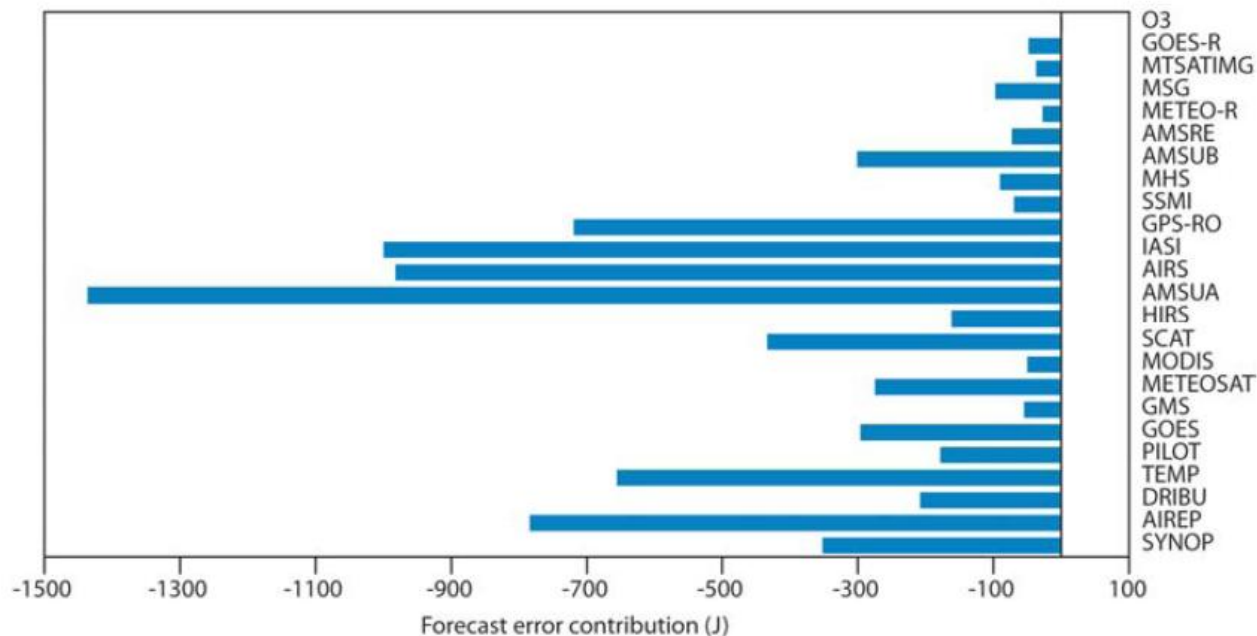
From Cardinali (ECMWF Tech. Memo. 599, 2009), See also, Cardinali, C, Monitoring the observation impact on the short-range forecast, Q. J. R. Meteorol. Soc. 135: 239–250 (2009)

A-Train Symposium: Pagano, October 26, 2010
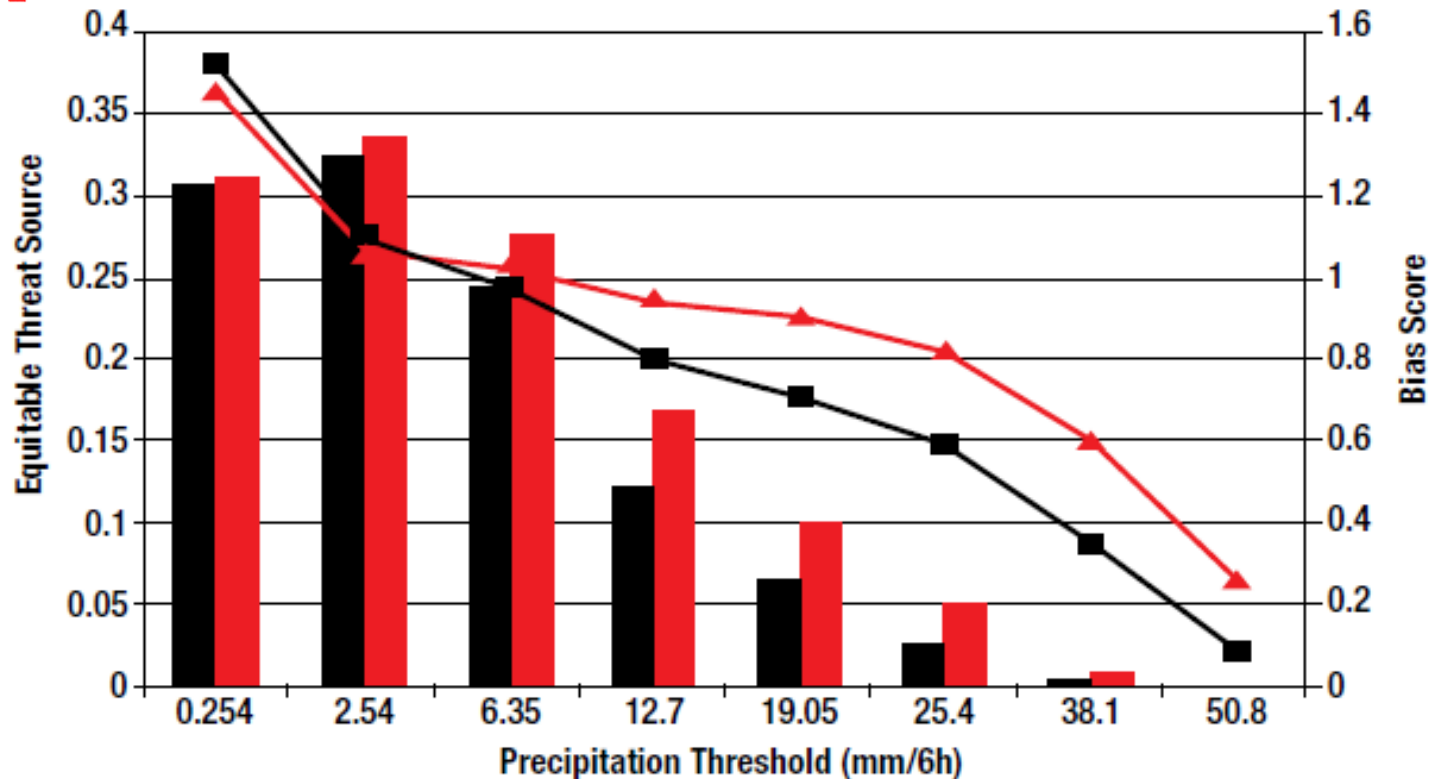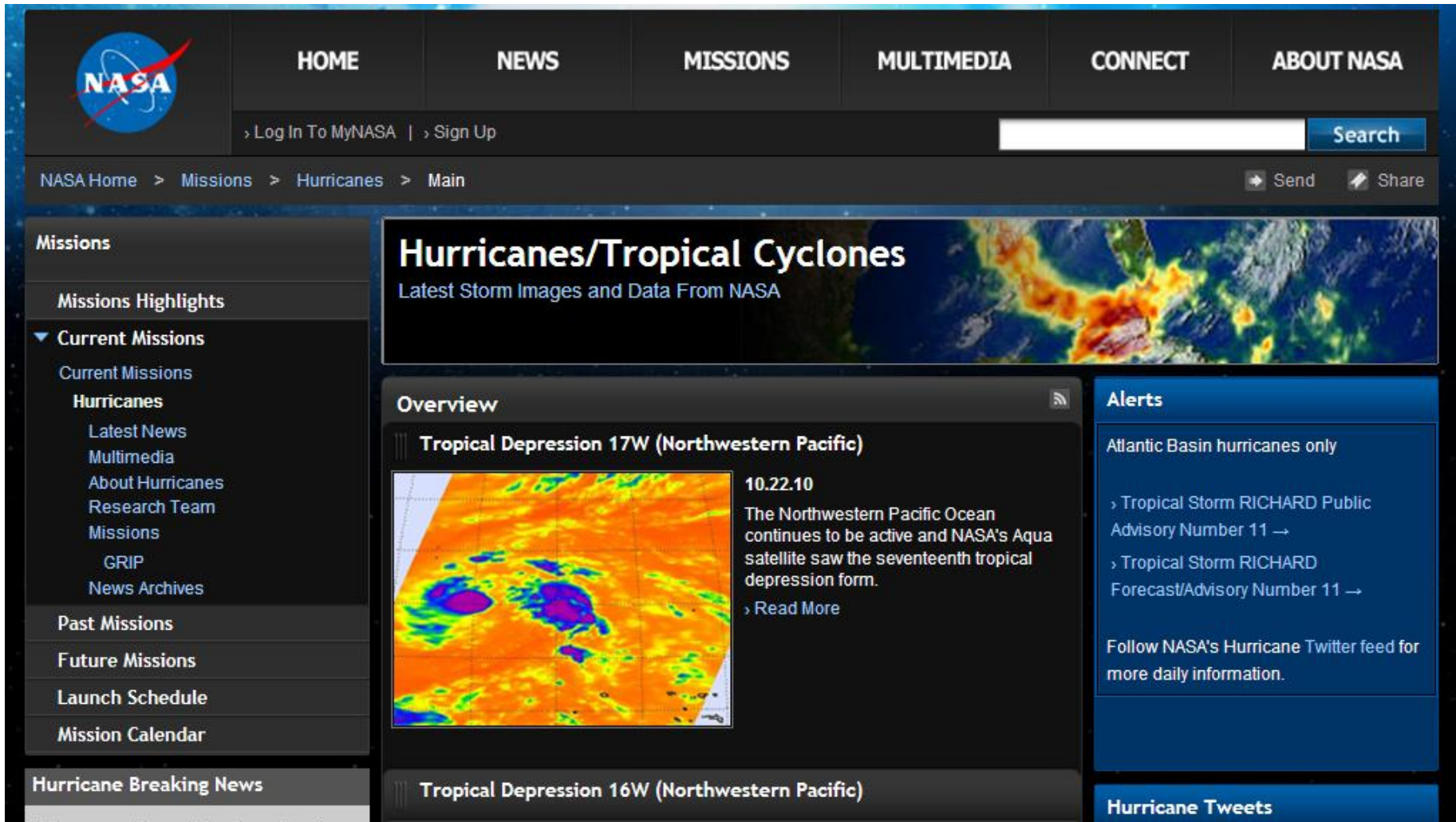
Figure 1. Overall 6-hr cumulative precipitation statistics for 37-day case study period. The bars represent equitable threat scores (left axis) and the lines represent bias scores (right axis). While black bar and line are for the control runs; red bar and line are for the AIRS runs.

McCarty, W., G. Jedlovec, and T. L. Miller (2009), Impact of the assimilation of Atmospheric Infrared Sounder radiance measurements on short-term weather forecasts, J. Geophys. Res., 114, D18122, doi:10.1029/2008JD011626.

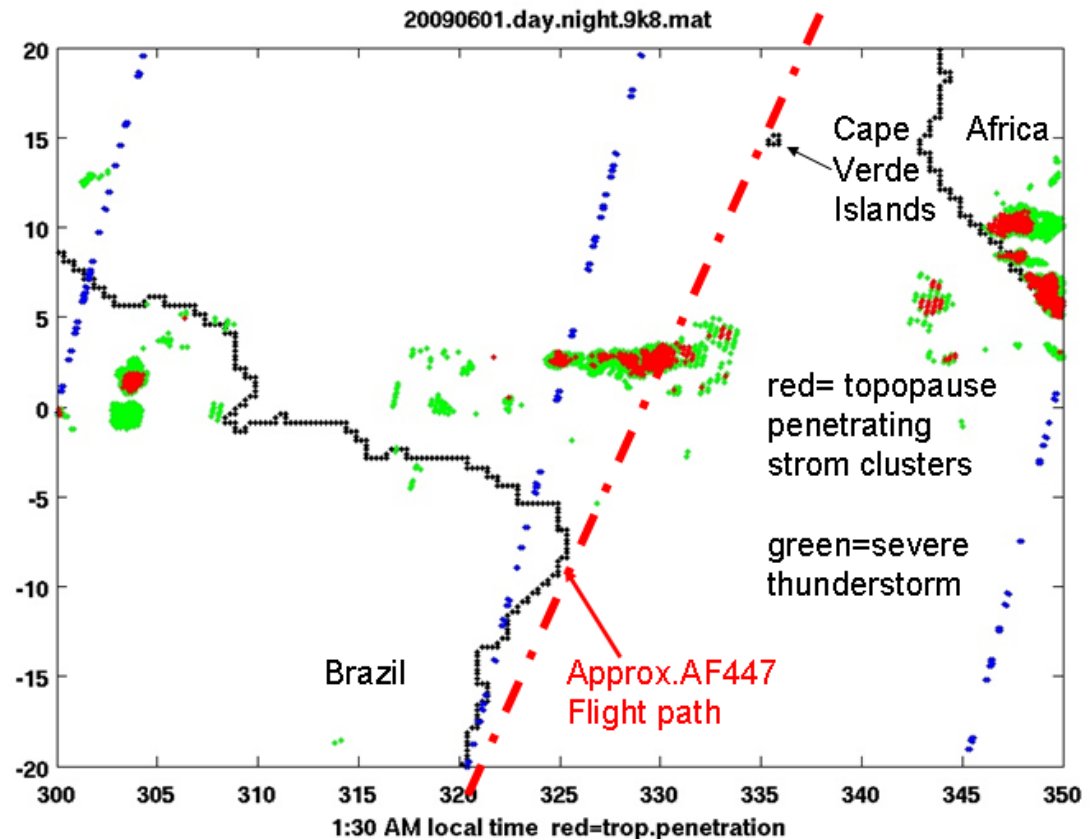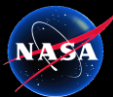# NASA Hurricane Portal Frequently Uses AIRS Near Real Time Imagery

http://www.nasa.gov/mission_pages/hurricanes/main/index.html

A-Train Symposium: Pagano, October 26, 2010

- AIRS uses IR to sense very cold (<220K) Cloud Tops

- Air France 447

- The red dashed line approximates the nominal flight path of Air France 447 at about 10 km altitude. Large clusters of extremely dangerous troposphere penetrating clusters of thunderstorms detected by AIRS are shown in red.

- The tops of these thunderstorms are near 20 km altitude. Clusters of severe thunderstorms reaching about 15 km in altitude are shown in green.

- Aumann (2009)

20090601.day.night.9k8.mat

Cape Verde Islands
Africa

red= topopause penetrating strom clusters

green=severe thunderstorm

Approx.AF447 Flight path

Brazil

1:30 AM local time red=trop.penetration

11

AIRS Greenhouse Gases

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

H_2O

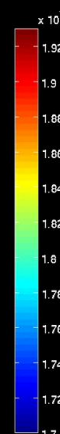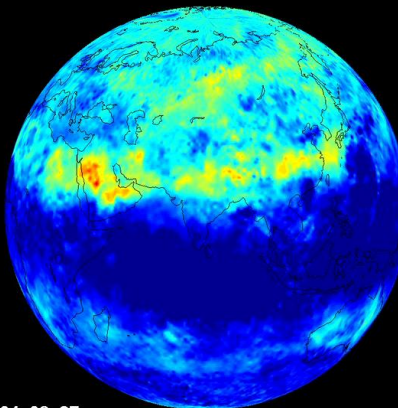500 mb Water Vapor (g/kg dry air)
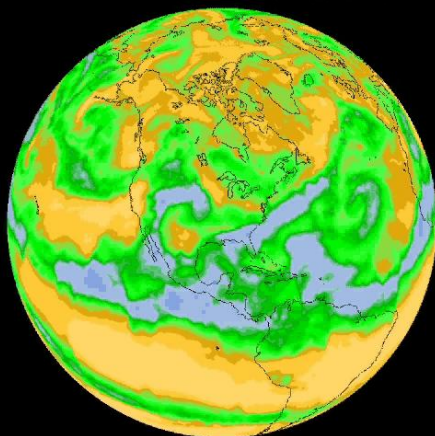
2005.08.01

CH_4

CH4 VMR at 200 mb (ppm):

2004_08_27

CO_2
Mid-Tropospheric CO_2 (ppm)
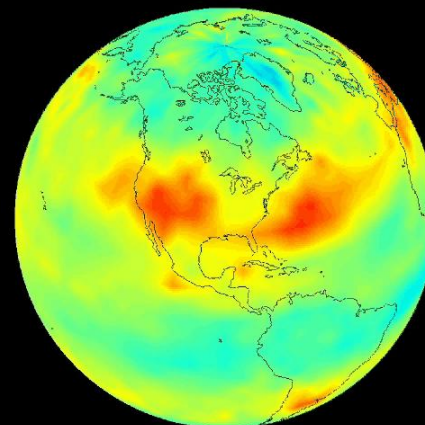
Pagano, JPL, 2009

Other AIRS Atmospheric Climate Products

500 mb Temperature (K)

2005.08.01

Temperature
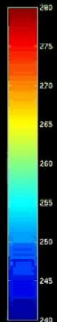
Cloud Fraction
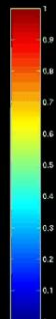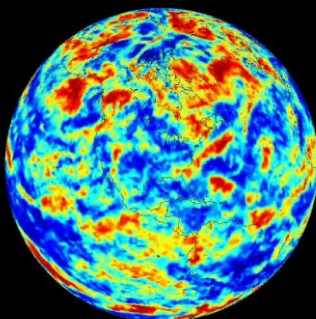
2005.08.01

Clouds

Total Column CO (molecules/cm^2)

5.08.01

CO
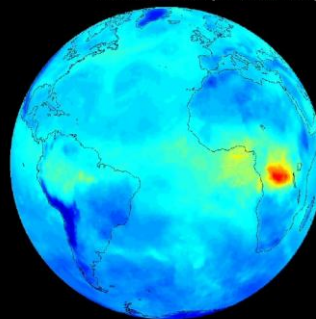
Total Column Ozone (DU)

01

O_3

AIRS Reduces Cyclone Position and Magnitude Error Globally

Impact of AIRS on 24hr Forecast of Sea Level Pressure

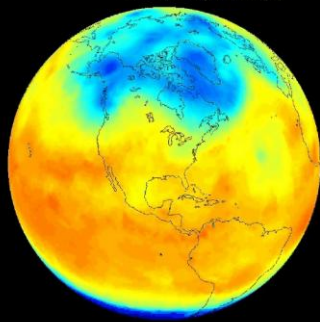Control 24hr Forecast

AIRS 24hr Forecast

NCEP AVN 24hr Forecast

Verifying Analysis

January 31, 2003 00Z
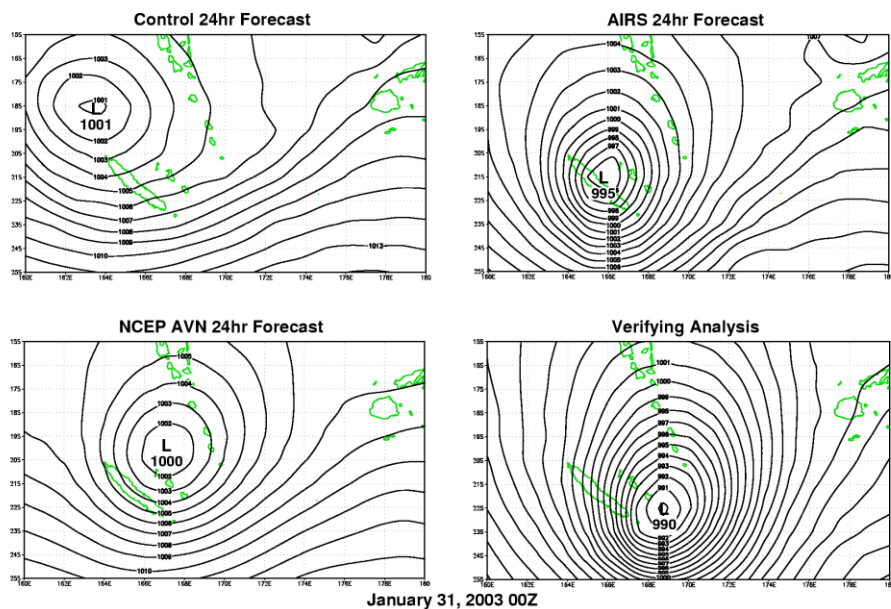
Global Extratropical Cyclone Forecast Error from 11 Five-day FVSSI Forecasts

CON = Control
CLR1 = Control+AIRS (clr,40S-40N)
CLR2 = Control+AIRS (clr)
PC = Control+AIRS (clr+partly cloudy)
ALL = Control+AIRS (all cloudiness)
PC+LAND = Control+AIRS (clr+partly cloudy with land)

Position Error

Magnitude Error

(R. Atlas/GSFC)

13
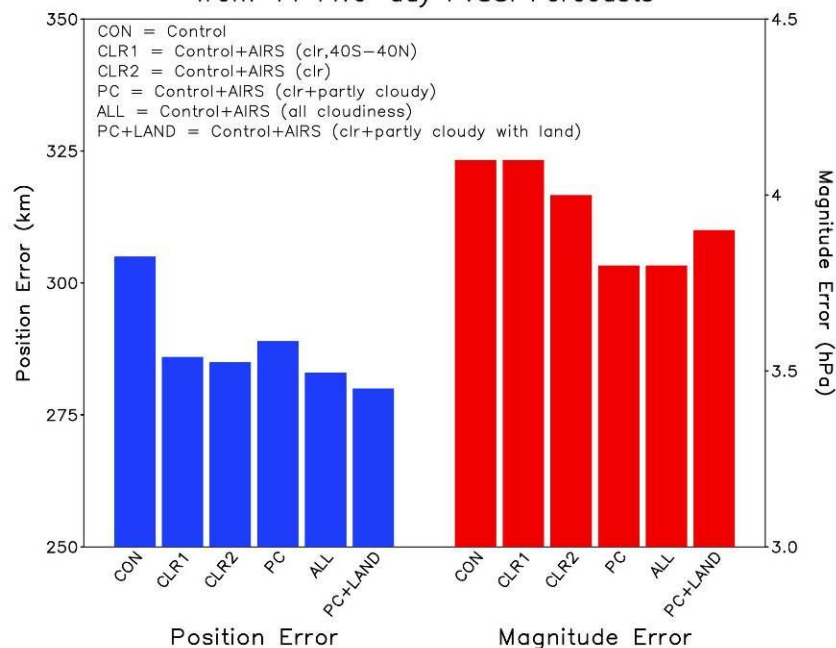
AIRS Data Improves Prediction of Hurricanes
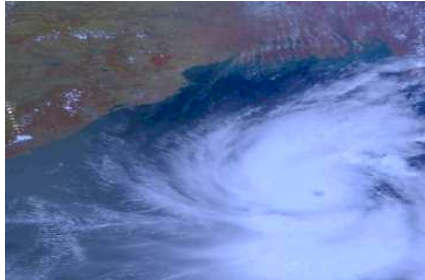
- Tropical Cyclone Nargis
- Killed over 140,000 People
- Worst Natural Disaster in history of Burma`
- O. Reale, GSFC, 2008

GEOS−5 Control Forecasts
Bay of Bengal Cyclone Nargis Tracks

**Control Run
Storms Dissipate**

	12z27Apr−12z3May Observed Track
	GEOS−5 Control FCs Init 00z27Apr
	GEOS−5 Control FCs Init 00z28Apr
	GEOS−5 Control FCs Init 00z29Apr
	GEOS−5 Control FCs Init 00z30Apr
	GEOS−5 Control FCs Init 00z01May
	GEOS−5 Control FCs Init 00z02May
	GEOS−5 Control FCs Init 00z03May
	? − Non−trackable

GEOS−5 AIRS (Retr.) Forecasts
Bay of Bengal Cyclone Nargis Tracks

**With AIRS Data
5 of 7 Make Landfall < 50 km**

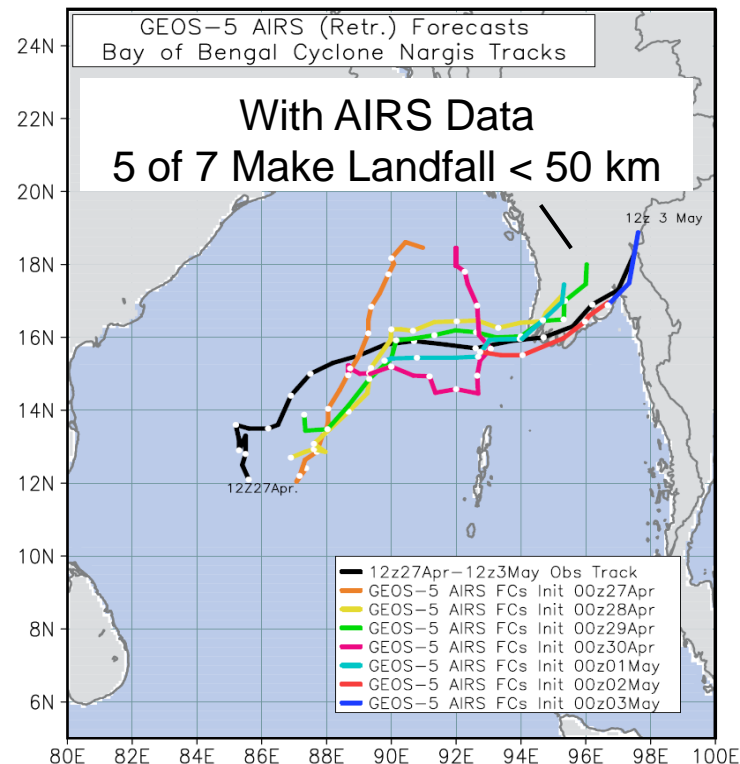|	
	12z27Apr−12z3May Obs Track
	GEOS−5 AIRS FCs Init 00z27Apr
	GEOS−5 AIRS FCs Init 00z28Apr
	GEOS−5 AIRS FCs Init 00z29Apr
	GEOS−5 AIRS FCs Init 00z30Apr
	GEOS−5 AIRS FCs Init 00z01May
	GEOS−5 AIRS FCs Init 00z02May
	GEOS−5 AIRS FCs Init 00z03May

Reale, O., W. K. Lau, J. Susskind, E. Brin, E. Liu, L. P. Riishojgaard, M. Fuentes, and R. Rosenberg (2009), AIRS impact on the analysis and forecast track of tropical cyclone Nargis in a global data assimilation and forecasting system, Geophys. Res. Lett., 36, L06812, doi:10.1029/2008GL037122. http://www.agu.org/journals/gl/gl0906/2008GL037122/

Figure 1. Precipitation accumulation associated with tropical cyclone Nargis from April 27 to May 3 from observations and CONTRL, RAD, and AIRS analyses.
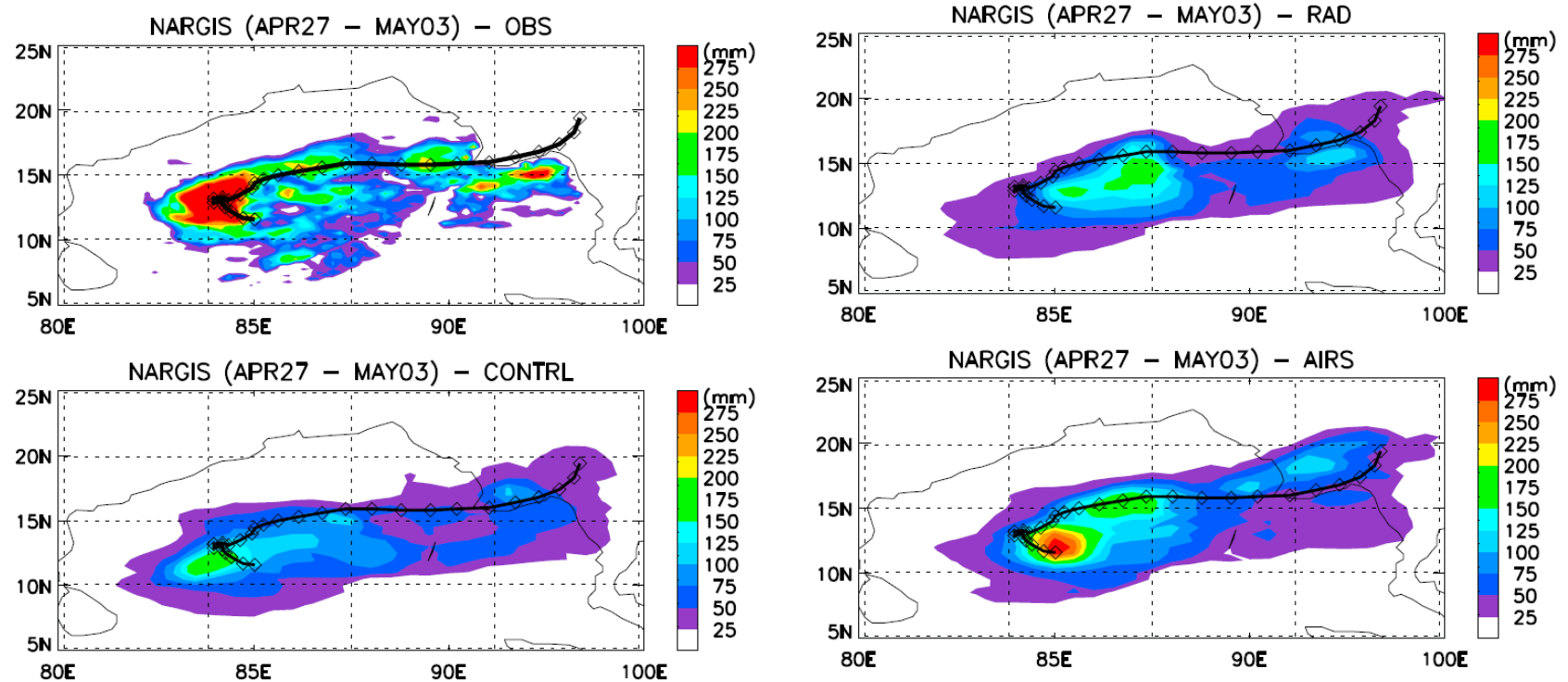
Zhou, Y. P., K.-M. Lau, O. Reale, and R. Rosenberg (2010), AIRS impact on precipitation analysis and forecast of tropical cyclones in a global data assimilation and forecast system, Geophys. Res. Lett., 37, L02806, doi:10.1029/2009GL041

New AIRS Near-Real-Time Skew-T Tool Online. High Interest by Forecasters

NASA Jet Propulsion Laboratory
California Institute of Technology

Skew-T Available within 3 Hours of Acquisition
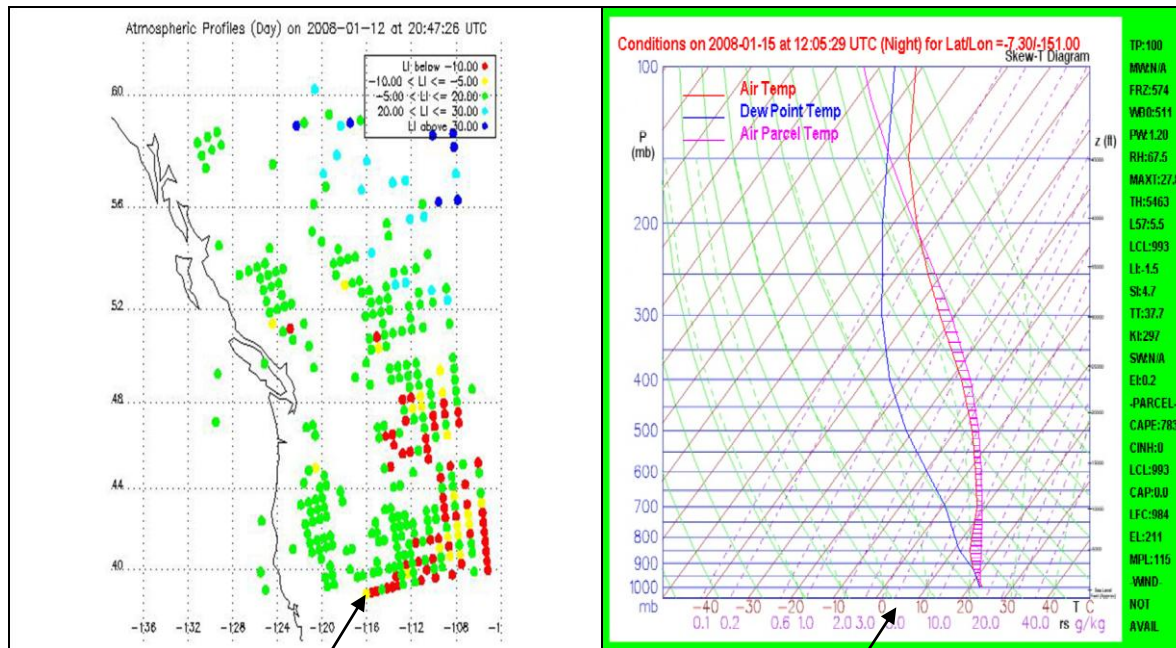
Click on Sounding

Receive Profile

Interested groups at recent American Meteorological Society conference include:

Air Force Weather
NOLL
Naval Oceanography
Penn State Meteorology
Bermuda Weather Service
Florida State University
Florida Inst. of Technology
DTM/Meteorologix
UNISYS
Meteorology Dept. at Norfolk
NOAA/NESDIS
SENASA - Madrid
MR1 - Japan
USAF

http://airsnrt.jpl.nasa.gov/SkewT_index.html

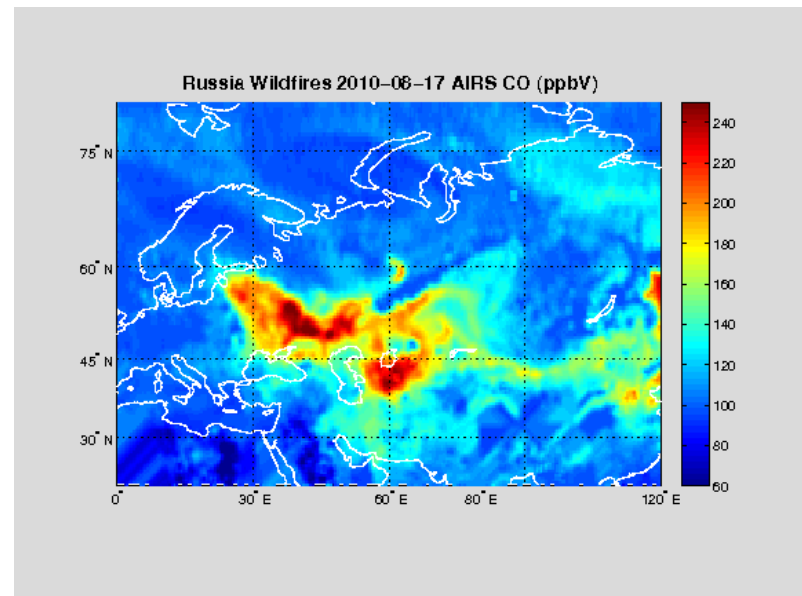**Northern California, 2008**
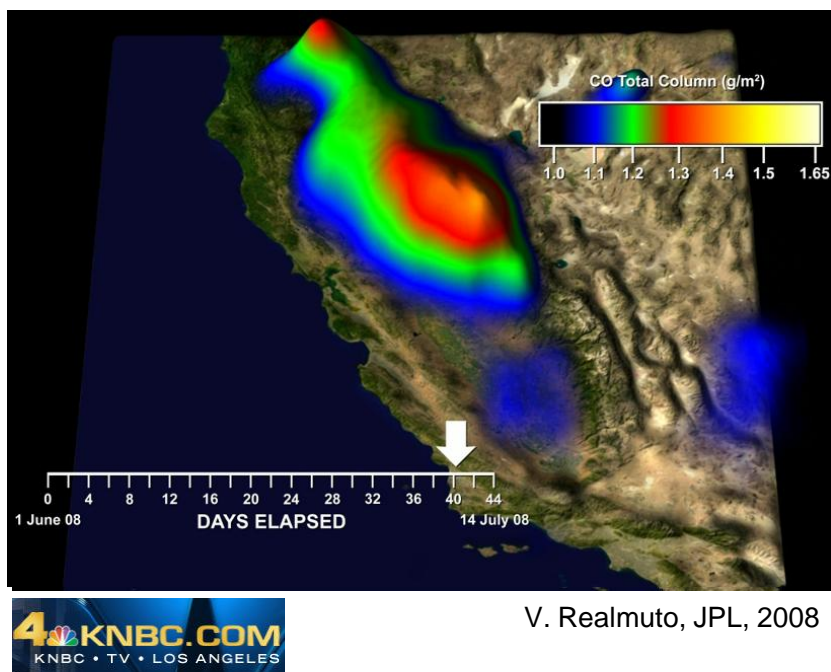
Station Fire, Angeles Forest, 2009

V. Realmuto, JPL, 2008
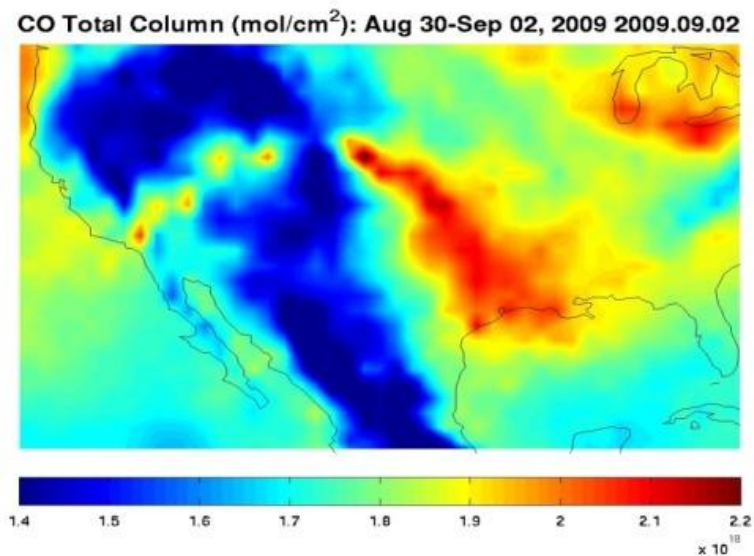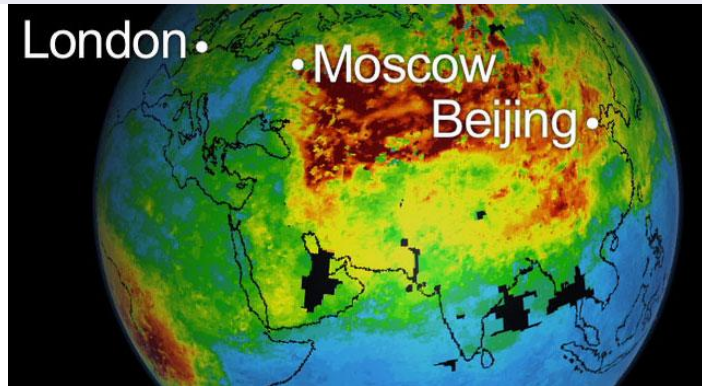
- Eyes on Earth posts AIRS CO of Russian fires
- AIRS imagery receives extensive news coverage
- HQ Request for real time information: Imagery, Data Files
- ftp://thunder.jpl.nasa.gov/AIRS/Russia/2010/08/

The New York Times
Wednesday, August 25, 2010
Opinion

DOT EARTH
Nine Billion People. One Planet.

August 11, 2010, 9:23 PM

NASA Tracks Pollution Flow from Russian Fires
By ANDREW C. REVKIN
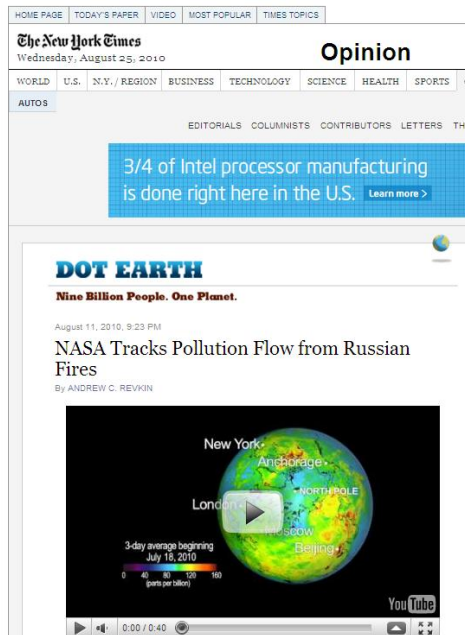
NASA has released video showing the pall of pollution spreading from the wildfires in and around Russia. (Here's a satellite-generated map of the fires.) The animation was created using data from the Atmospheric Infrared Sounder instrument on NASA's Aqua satellite. The colors reflect levels of carbon monoxide at an altitude of about 18,000 feet, with the gas providing an indirect indicator of other emissions.

Russia Wildfires 2010-08-17 AIRS CO (ppbV)

A-Train Symposium: Pagano, October 26, 2010

Ejyafyallajokul,
Dr Fred Prata
Norwegian Institute for Air
Research, Kjeller, Norway

AIRS SO2 flag alert sent to Washington
Volcanic Ash Advisory Council by NOAA as
part of near real time alert system

A-Train Symposium: Pagano, October 26, 2010

NASA
Jet Propulsion Laboratory
California Institute of Technology

AIRS Mid-Troposphere CO2 Product (Chahine)

AIRS Mid–Tropospheric CO2. July 2003, V5 Day 16 x 31

365   370   375   380

Recent Publications:
1. Chahine, M. T., L. Chen, P. Dimotakis, X. Jiang, Q. Li, E. T. Olsen, T. Pagano, J. Randerson, and Y. L. Yung (2008), Satellite remote sounding of mid-tropospheric CO2, Geophys. Res. Lett., 35, L17807, doi:10.1029/2008GL035022.
2. Strow, L. L., and S. E. Hannon (2008), A 4-year zonal climatology of lower tropospheric CO2 derived from ocean-only Atmospheric Infrared Sounder observations, J. Geophys. Res., 113, D18302, doi:10.1029/2007JD009713.

7 Years of AIRS Mid Tropospheric Daily/Global CO2 Data Now Available*

Validated to 1-2 ppm: Chahine (2009)

AIRS Project Under Contract with NASA To Retrieve Stratosphere and Near Surface CO_2

20

Global Models

Year	Resolution	Model
1974	450	Global GIIS 4dx5d
1976	250	GISS
1980	300	Spectral NML
1998	100	GEOS-3
1999	50	GEOS-4
2009	35	NCEP
2004	25	GEOS-4,5
2009	3.5	GEOS-5 Limited Run

Legend:
— HIRS
— AMSU
— AIRS/CRIS/IASI
- - ATMS
- - CrIS
♦ GCM
— Expon. (GCM)

GCM Trendline

?
Need 1-2 km by 2020

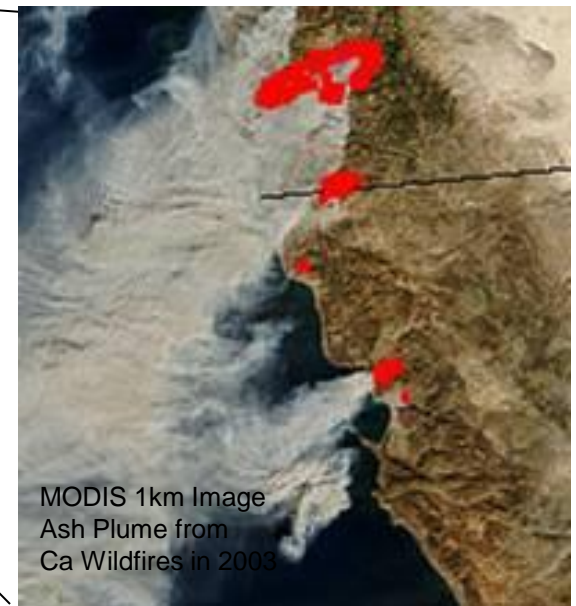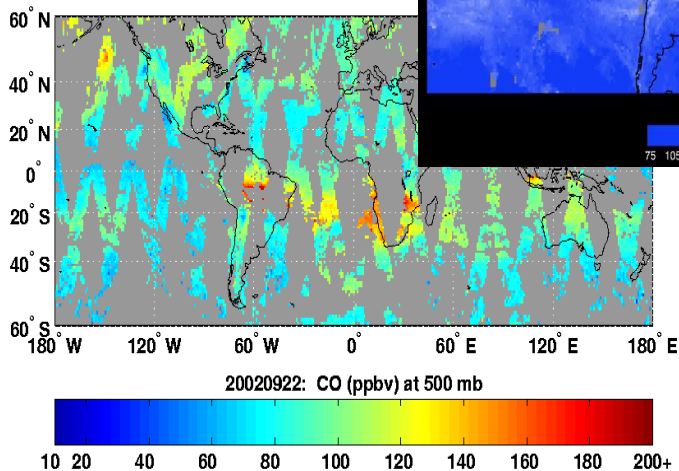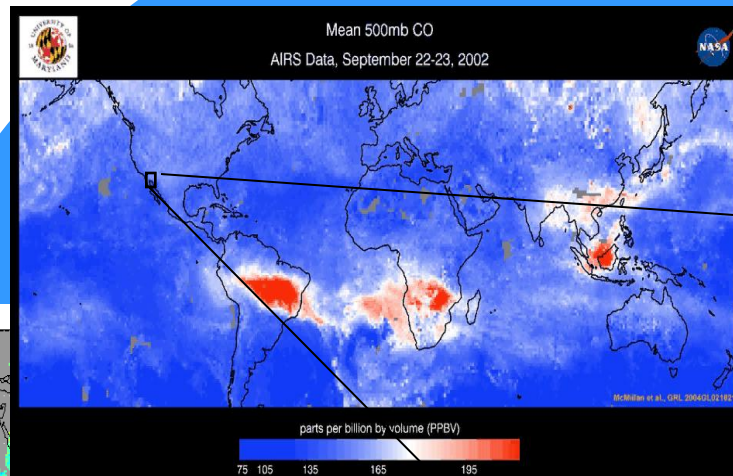*A-Train Symposium: Pagano, October 26, 2010*

Technology Evolution Now Allows AIRS Spectral Resolution with MODIS Spatial Resolution

Current: AIRS CO, Grating, 15 km IFOV Daily Global

Higher Spatial Resolution + Global Coverage

MOPITT CO Gas Cell 22 km IFOV Monthly Global

MODIS 1km Daily Regional Coverage

Mean 500mb CO
AIRS Data, September 22-23, 2002

parts per billion by volume (PPBV)

75 105 135 165 195

20020922: CO (ppbv) at 500 mb

10 20 40 60 80 100 120 140 160 180 200+

MODIS 1km Image
Ash Plume from
Ca Wildfires in 2003

A-Train Symposium: Pagano, October 26, 2010

NASA Jet Propulsion Laboratory
California Institute of Technology

- AIRS in Good Health. Expect to be operational beyond 2018
- Wide range of data products available from single instrument to support:
  - Weather, Climate, Composition
- Weather and Operational Applications Highlights include
  - Highest impact to forecasts of any single sensor (next to IASI)
  - Improves Regional Forecast of Precipitation
  - Composition Products provided in Near Real Time
    - SO2 for Aviation Industry
    - CO from Wildfires
- Higher Spatial Resolution will improve applications of AIRS Data
- NASA Sounding Science Community Workshop Next Week in MD
- See: http://airs.jpl.nasa.gov

A-Train Symposium: Pagano, October 26, 2010